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Paper Wasps of the Genus *Polistes* in Eastern Lesser Sunda Islands (Hymenoptera: Vespidae)

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Abstract.—Social wasps of the polistine genus *Polistes* in the eastern part of the Lesser Sunda Islands (Sumba, Flores and Timor Islands) were examined based on the specimens recently collected by ourselves. The following four species are recognized: *P.* (*Gyrostoma*) *diabolicus*, *P.* (*G.*) *tenebricosus*, *P.* (*Polistella*) *callimorpha* and *P.* (*Polistella*) *sagittarius*. We include new records of *Polistes* wasps from Sumba Island. Nests and mature larvae of *P. diabolicus* and *P. callimorpha*, and males of *P. diabolicus* are described for the first time. New synonymies included are: *Polistes sulcatus* Smith, 1852, *P. hoplitus* de Saussure, 1853, *P. tenebricosus leopoldi* Bequaert, 1934, *P. tenebricosus nigrosericans* Bequaert, 1940, and *P. tenebricosus sibuyanensis* Bequaert, 1940, all under *P. tenebricosus* Lepeletier, 1836; and *P. sagittarius indonesicus* Bequaert, 1940, under *P. sagittarius* de Saussure, 1853.

Polistes Latreille, 1802, consisting of 205 species, is one of the largest genera in the social wasp subfamily Polistinae and is the only social wasp genus that has a cosmopolitan distribution (Carpenter 1996a). The genus is currently divided into four subgenera: nominate subgenus, *Polistella* Ashmead, 1904, *Gyrostoma* Kirby, 1828, and *Aphanilopterus* Meunier, 1888. The first three subgenera are, except for a few introduced species, restricted to the Old World, with the subgenus *Polistes* being mainly temperate, and *Polistella* and *Gyrostoma* being more tropical. *Aphanilopterus* is of the New World. While subgeneric taxonomy of *Polistes* has been rather well studied (van der Vecht 1972, Richards 1973, Kojima and Kojima 1988, Carpenter 1996b) and the four subgenera currently recognized are more or less well defined, species-level taxonomy of the genus, especially of the species in the Old World tropics, is still poorly resolved.

The Indonesian fauna of *Polistes* is, like that of other terrestrial arthropods, of special interest from a biogeographical points of view. Twenty species so far recorded from Indonesia can be divided into five groups in terms of their distribution patterns: (1) species widely distributed from continental Asia to islands of Indonesia (*P. olivaceus* (DeGeer, 1773), *P. rothneyi* Cameron, 1900, *P. sulcatus* Smith, 1852, *P. tenebricosus* Lepeletier, 1836, *P. sagittarius* de Saussure, 1853, *P. stigma* (Fabricius, 1793)), usually represented by many local color forms; (2) species occurring only in the Malay Peninsula and Borneo Island (*P. meadeanus* (von Schulthess, 1913)); (3) species restricted to Java and Lesser Sunda Islands (*P. diabolicus* de Saussure, 1853); (4) those restricted to New Guinea Island, but often occurring also on its adjacent islands including the Moluccas (*P. tepidus* (Fabricius, 1775), *P. bambusae* Richards, 1978, *P. elegans* (Smith, 1859), *P. melanopterus* Cameron, 1911, *P. nigrifrons* Smith, 1859, *P. utakwae* Meade-Waldo, 1916), usually represented by island-specific color forms; and (5) species confined to small island(s)

in a restricted area (*P. buruensis* Petersen, 1990, on Buru; *P. extraneus* Kirby, 1883, on Maru; *P. lateritius* Smith, 1857, on Ambon, Seram, and Saparua; *P. mertoni* du Buysson, 1913, on Aru; *P. callimorpha* de Saussure, 1853, on Timor; *P. simulatus* Smith, 1860, on Halmahera, Morotai, Obi, Bacan and Kayoa).

The eastern Lesser Sunda Islands include Sumba, Flores and Timor as major islands. The region should be important in understanding diversification and dispersal processes of terrestrial arthropods in the transition areas between the Oriental region and New Guinea and/or Australia. This could also be the case for *Polistes* wasps. Three species (*P. diabolicus*, *P. tenebricosus* and *P. sulcatus*) have so far been recorded from Flores, and *P. diabolicus* and *P. callimorpha* from Timor, while no *Polistes* species has been known from Sumba Island. Those records of *Polistes* species from Flores and Timor are based on research carried out more than 50 years ago (de Saussure 1853–58, du Buysson 1913, Bequaert 1934, von Schulthess 1935).

The present study discusses the taxonomy and distribution of *Polistes* wasps in these three islands based on adult wasps, nests and larvae collected during our recent research trip to the region.

MATERIALS AND METHODS

Field collection of the wasps and their nests was conducted in Sumba and Flores Island and the eastern part of Timor Island by us except FS during the period from 23 January to 3 February 2003.

Adult morphology was observed on pinned and dried specimens (including those emerging from the nests after nest collection) under a stereoscopic dissecting microscope. Male genitalia were dissected out, cleared in 10% KOH and observed in glycerin under a stereoscopic dissecting microscope.

Mature (=fifth instar) larvae were extracted from nest cells within one day after collection of nests, and then they were kept in 80% ethanol. Larvae were observed for their general appearance including coloration under a stereoscopic dissecting microscope. Some larvae were cleared in hot 10% KOH, heavily stained with acid fuchsin, dissected, and mounted on a glass slide in Canada balsam to observe microscopic structure under a compound microscope. Terminology of larval morphology follows Kojima (1998); first to third thoracic segment and first to tenth abdominal segment are abbreviated as T1-3 and A1-10, respectively.

The nests collected were measured for the length and thickness of nest pedicel and the distance between opposite sides of a cell containing pupae or having trace of cocoon caps ("cell width") to the nearest 0.1 mm with vernier calipers. Thickness of the cell wall was measured with a micrometer to the nearest 0.01 mm.

Materials examined are deposited in the Museum Zoologicum Bogoriense and Natural History Collection at Ibaraki University. FS and JK are responsible for all arguments relating to the treatment of subspecies.

KEY TO *POLISTES* SPECIES IN WESTERN PART OF LESSER SUNDA ISLANDS

1 Clypeus not produced above anterior tentorial pits (Figs 5, 8). Pronotal fovea present. Prestigma about as long as or longer than half length of pterostigma (Figs 1, 2) . . . . . 2 (subgenus *Gyrostoma*)

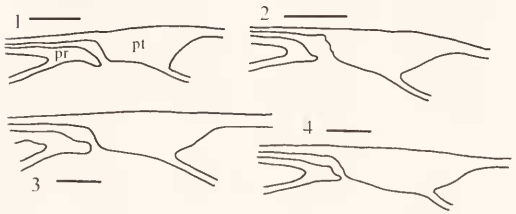
– Clypeus dorsally produced well above anterior tentorial pits (Fig. 13). Pronotal fovea, epicnemial carina and dorsal groove all absent. Prestigma short, distinctly shorter than half length of pterostigma (Figs 3, 4) . . . . . 3 (subgenus *Polistella*)

2 Smaller species; forewing length 11–16 mm. Epicnemial carina and dorsal groove present (Fig. 11). Body black, extensively marked with bright-yellow . . . . . *P. diabolicus*

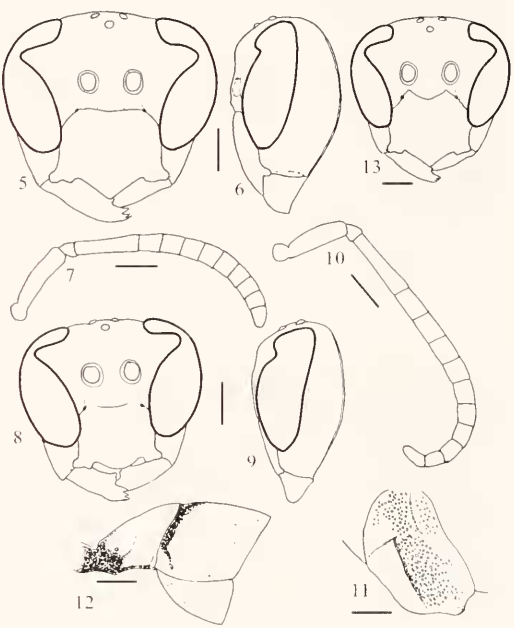
– Larger species; forewing length 17–22 mm. Epicnemial carina and dorsal groove both absent. Body ferruginous to orange-brown; first two metasomal terga extensively marked with yellow, or nearly entirely dark orange-brown ..... *P. tenebricosus*

3 Smaller species; forewing length 8.5–11 mm. Gena proportionally narrow, in profile about 0.6 times as wide as eye in female. Body black, extensively marked with brown and yellow; wings transparent, with dark spot in marginal cell ..... *P. callimorpha*

– Larger species; forewing length 18–20 mm. Gena wide, in profile about 0.9 times as wide as eye in female. Body ferruginous to dark brown, sometimes with dark orange-brown bands on second and/or first metasomal terga; wings entirely strongly fuscous ..... *P. sagittarius*



Figs 1–4. Prestigma (pr) and pterostigma (pt) of fore wing. 1, *Polistes diabolicus*. 2, *P. tenebricosus*. 3, *P. callimorpha*. 4, *P. sagittarius*. Scale bars: 0.5 mm.



Figs 5–13. Adult wasp. 5–12, *Polistes diabolicus*. 13, *P. sagittarius*. 5–7, 11, 13, female. 8–10, 12, male. 5, 8, 13, head, in frontal view. 6, 9, head, lateral view. 7, 10, left antenna. 11, mesepisternum. 12, first two metasomal segment, lateral view. Scale bars: 1 mm.

DESCRIPTIONS AND TAXONOMIC NOTES ON EACH SPECIES

Polistes (*Gyrostoma*) *diabolicus* de Saussure, 1853

This species was originally described based on females from Java and Timor (de Saussure 1853–58: 68), and was recorded also from Lombok, Flores, and Kai Islands (von Schulthess 1935); its occurrence on Kai Islands needs confirmation as discussed later. The males, mature larvae and nests are described herewith for the first time; the present study also includes a new record of this species from Sumba Island.

Male.—Female characteristics that differ distinctly from that of males are given in brackets. Body length (head + mesosoma + first two metasomal segments) 12–14 [11.5–15.5] mm; forewing length 14–16.5 [12.5–16] mm. Head in frontal view (Fig. 8) about 1.2 times as wide as high [1.15; Fig. 5], about as wide as mesosoma excluding tegulae; inner eye margins barely convergent ventrally, distance between them at vertex about 1.1 times longer than distance at clypeus; clypeus nearly flat (Fig. 9), with slight truncation laterally [weakly convex; Fig. 6], rounded quadrate (Fig. 8) [transverse excluding ventral projection; Fig. 5], about 1.1 times wider than high, with ventral margin broadly rounded [produced ventrally]; gena proportionally narrower than in female, in profile (Fig. 9) little more than 0.8 times as wide as [nearly as wide as; Fig. 6] eye, slightly

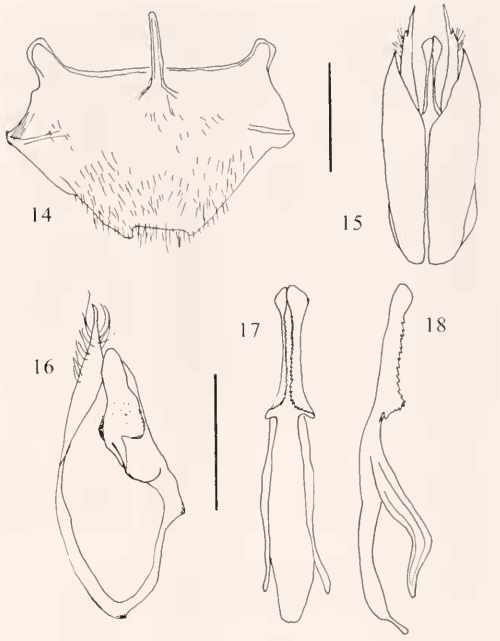
raised into blunt ridge just behind eyes [without such "ridge"]; ocelli arranged in nearly equilateral triangle, space between posterior ocelli about 1.3 times their diameter, and half as wide as distance to inner eye margin. Antenna (Fig. 10) not very different from that of female (Fig. 7); scape weakly swollen medially [slightly curved, not swollen medially], about 3.5 [4] times as long as wide; first flagellomere about 3.75 [3.3] times as long as its own apical width, distinctly longer than length of second and third flagellomeres combined [about equal to length of second to fourth flagellomeres combined]; terminal flagellomere very weakly curved, rounded apically, about twice as long as its own basal width [bullet shaped, about 1.25 times as long as its own basal width]; fifth to terminal flagellomeres with ill-defined flat area beneath [without tyloides or such flat areas].

Mesosoma about 1.7 times longer than wide. Epicnemial carina weaker than in female. Propodeum with median depression shallow, with transverse striae; propodeal orifice narrowed above, but not pointed at dorsal end, about 2.5 times as long as wide.

First metasomal tergum slightly longer than wide, in profile (Fig. 12) abruptly swollen dorsally just behind basal slit for reception of propodeal suspensory ligament, then dorsally swollen gradually toward posterior margin; second tergum wider than long, little less than 1.5 times as wide as first tergum; second sternum more strongly convex than tergum.

Head feebly punctured, except for frons, where punctures are sparse but distinct; mesosoma with sparse punctures, except in unpunctured anteroventral area of mesepisternum; metapleura barely punctured, with a few, short, transverse striae ventrally; punctures on propodeum larger than those in other part, present between striae; metanotum barely punctured.

Terminal sterna as in Fig. 14; apical margin with a pair of subtriangular pro-



Figs 14–18. *Polistes diabolicus*, male. 14, terminal sterna, flattened. 15, genitalia, dorsal view. 16, inner aspect of paramere with digitus and volsella. 17, aedeagus, ventral view. 18, aedeagus, lateral view. Scale bars: 1 mm.

jections. Parameral spine (Figs 15, 16) thick, with tuft of hairs; lamina volsellaris sclerotized and separated from cuspis (jointed by membrane); digitus (Fig. 16) rather large, narrowed apically; rods forming aedeagus (Figs 17, 18) serrate ventrally, about 0.7 times as long as basal apodeme.

Black, extensively marked with bright yellow as follows: front of head below level of anterior ocellus, paired short band behind posterior ocelli, gena mostly, mandible except for dark brown teeth, pronotum, paired wide submedian bands and large spot beside tegula on mesoscutum, axilla, scutellum except for posterior margin, axillura, metanotum except for posterior margin, tegula except on inner margins, most of anterior part of and scrobal spot (sometimes reduced in size or absent) on mesepisternum [anteroventral part black, scrobal spot usually large in female], spot at anterodorsal corner of dor-

sal metapleura, spot at posterodorsal corner of ventral metapleura (sometimes absent), large lateral spots on propodeum, spot on propodeal valvula. Antenna yellow; scape black dorsally, pedicel black basally; flagellum ferruginous above or entirely ferruginous. Legs yellow; all coxae black dorsally; fore femur largely black; fore tibia and tarsi irregularly tinged with ferruginous, black dorsally; mid femur black dorsally; mid tibia largely ferruginous, with black markings; mid basitarsus black basally; hind femur black, with longitudinal yellow stripe; hind tibia black, with yellow spot near apical margin, hind basitarsus largely black. Metasoma dull yellow; basal part of first tergum, first sternum (often largely yellow), base of second tergum black [third and fourth terga sometimes with basal black bands].

Mature larva.—Cranial width 2.3–2.7 mm (n = 21). Cranium and mouthparts blackish brown; vertex slightly paler; ecdysial sulcus unpigmented; parietal band and ventral margin of labrum slightly paler. Venter of T1-3 except for posterior margins and anterior half of A1 venter dark brown.

Cranium in frontal view (Fig. 19) suboval, widest slightly below level of antennae, about 1.25 times as wide as high; in profile barely emarginate posteriorly (Fig. 20); front face including clypeus covered with sparse, short (about 0.07 mm long) setae. Outer one-third of parietal band reticulate. Ecdysial sulcus narrow, very shallow. Labrum (Fig. 22) narrowed where it joins clypeus, broadly and very shallowly emarginate medioventrally, with about 50 punctures bearing short (about 0.06 mm) setae in ventral half; ventral margin with a few, low conical papillae and sparse, minute spicules. Palate (Fig. 23) medially with about 20 small, conical papillae; ventral margin and ventrolateral part with sparse, minute spicules. Mandible (Fig. 24) with three teeth; median tooth nearly twice as long as inner and outer teeth. Maxilla covered with about 50 setae (about 0.06 mm); upper surface with sparse, minute spicules; maxillary palpus (Fig. 26) simple in shape, nearly flat apically, with 3–6 apical sensilla; in one specimen, short additional palpus with apical sensillum present adjacent to right maxillary palpus (Fig. 27); galea simple in shape, more slender than maxillary palpus, with 2–4 apical sensilla. Prementum (Fig. 25) subcircular, with several setae in area dorsal to each labial palpus and about 50 setae in area ventral to labial pulpi; labial palpus (Fig. 28) simple, shorter than maxillary palpus, flat apically, with 4–6 apical sensilla. Postmentum (Fig. 25) small; surface with sparse setae.

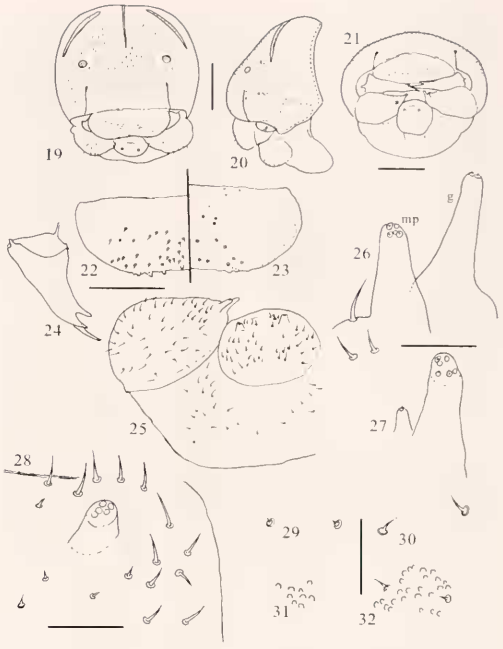
Body integument covered with scattered, short setae; setae on T1-3 venter (Fig. 29) shorter than those on other body surface (Fig. 30); dorsal lobes of abdomen bare. Spicules on body integument rounded apically (Figs 31, 32); T1-3 venter (except for posterolateral margins of T2 and T3) and A9 and A10 (except for anterior margin of each segment) lacking spicules. Second spiracle smaller than other spiracles, about 0.8 times as wide in diameter as others; spiracular atrium bare.

Nest.—Five nests were collected in Kupang, Timor Island (Table 1), of which PT-4 was before the appearance of pupae; others had produced adults from the nests. In all the four nests with pupae, "tandem brood" was recognized, that is, one and the same cell was occupied at the same time by a pupa (or rarely a mature larva) and an egg or a young larva, the phenomenon typically found in the subgenus *Gyrostoma* (Yamane and Okazawa 1977).

Three of the five nests (PT-2, -5, -6) were made on twigs of trees, PT-4 under eaves of a nipa house, and PT-3 under a leaf of an unidentified broad-leaf tree. Structural characters are as follows: comb nearly concentric, horizontal, and directed downward, bell-shaped with upper surface strongly convex in earlier stage of nest development (Fig. 33), more or less hat-

shaped in larger nests (Fig. 34), with lower surface (corresponding to open ends of cells) nearly flat, gray to brownish gray, but dark brown around pedicel attachment due to coating of salivary secretion of adult wasps. Pedicel single, shiny dark brown due to coating of salivary secretion, with longitudinal ridges (indicating that the thickening of pedicel is made not only by repeated coating of secretion but also by application of plant fibers), 4.1–7.1 mm (n = 5) long, 1.3–1.6 mm (n = 5) thick near mid-length, attached to periphery of first cell base, so that the pedicel is actually attached to the base of face shared by the first and second cells. Cells barely diverging toward open end, hexagonal in shape at open end when they are surrounded by neighboring cells; cell width, mean ± SD = 5.8 ± 0.3 mm (range 5.3–6.4 mm, n = 35); cell wall 0.06–0.18 mm (n = 5) thick, made of long fibers, sometimes extended beyond cocoon caps to make excess space in which eggs were laid. Cocoon caps nearly white, slightly domed, usually projecting well beyond rim of cell, except in case of excess elongation of cell wall.

Adult wasps examined.—Flores: 1♀, 08°44′S 121°45′E, Detusoko, Ende, 26.i.2003, JK; 3♀2♂, 08°45′S 121°51′E, Wolowaru, Ende, 26.i.2003, JK. Sumba: 1♀, 09°42′S 119°53′E, Lewa, Sumba Timur, 30.i.2003, JK & RU (**NEW RECORD** for the island). West Timor: 4♀, 09°57′S 124°09′E, Batuputih, Timor Tengah Selatan, 1.ii.2003, JK (1♀, Nest#PT-6); 9♀, 09°59′S 124°01′E, Takari, Kupang, 1.ii.2003, JK (4♀, Nest#PT-5); 1♀, 10°06′S 123°50′E, Kupang Timor, Kupang, 1.ii.2003, JK; 1♀, 10°13′S 123°50′E (360m alt.), Amarasi, Kupang, 2.ii.2003, JK; 2♀, 10°06′S 123°50′E, Amarasi, Kupang, 2.ii.2003, JK; 26♀6♂, 10°12′S 123°40′E, Fenonisa, Central Kupang, 23.i.2003, JK (7♀, Nest#PT-3; 19♀6♂, Nest#PT-2); 1♀, 10°10′S 123°40′E, Penfui, Central Kupang, 23.i.2003, JK.



Figs 19–32. Mature larva of *Polistes diabolicus*. 19, head, frontal view. 20, head, lateral view. 21, head, ventral view. 22, labrum. 23, palate. 24, mandible. 25, maxilla, prementum and part of postmentum. 26, apical part of maxilla, showing maxillary palpus (mp) and galea (g). 27, galea. 28, labial palpus and structures around it. 29–32, setae and spicules on body integument (29, T3 venter; 30, A1 venter; 31, A3 venter; 32, T2 dorsum). Scale bars: 1 mm (19–21), 0.5 mm (22–25), 0.1 mm (26–32).

Polistes (*Gyrostoma*) *tenebricosus* Lepeletier, 1836

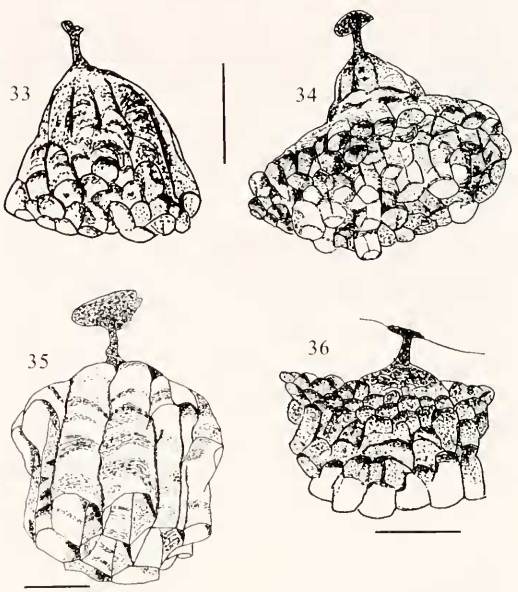
Polistes tenebricosa Lepeletier, 1836: 529.
Polistes sulcatus Smith, 1852: 38. NEW SYNONYMY.
Polistes hoplitus de Saussure, 1853, in de Saussure, 1853–1859: 55. NEW SYNONYMY.
Polistes tenebricosus var. *leopoldi* Bequaert, 1934: 9. NEW SYNONYMY.
Polistes tenebricosus var. (or subsp.) *nigrosericans* Bequaert, 1940: 266. NEW SYNONYMY.
Polistes tenebricosus var. (or subsp.) *sibuyanensis* Bequaert, 1940: 266. NEW SYNONYMY.

Bequaert (1934) treated *P. sulcatus* Smith, 1852 as a variety of *P. tenebricosus*, the treatment followed by Das and Gupta (1983, 1989) but as a subspecies. Richards (1973) proposed the subgenus *Nygmopol-*

istes with *P. sulcatus* as the type species. Finally Starr (1992), following advice from Sô. Yamane as personal communication, mentioned that "there are distinct differences in the abdomen [=metasoma] and nest between specimens from Java and Taiwan . . . I tentatively treat the species found in Taiwan as *P. sulcatus*" (p. 123), the treatment followed by Carpenter's (1996a) checklist of *Polistes* species. According to Sô. Yamane (personal communication), the wasps from Sumatra [not Java] have the first metasomal tergum with the anterodorsal angle more sharply angled and the second metasomal sternum more strongly swollen ventrally than the wasps from Taiwan; nests are also different, that is, the nests of the wasps in Sumatra are hat-shaped, while those from Taiwan are bell-shaped. The specimens that we collected in Flores include wasps with both types of metasoma (Figs 37, 40), but they also include specimens that have metasomata of intermediate shapes (Figs 38, 39), incorporating the extremes. As shown for *P. diabolicus*, the nest shape may differ according to the size that a given nest can attain.

Bequaert (1934, 1940) recognized, based on color pattern, six local varieties (including *sulcatus*) in *P. tenebricosus*, all but "*sulcatus*" being currently treated as subspecies (see Carpenter 1996a); nominate subspecies, *hoplitus* de Saussure, 1853, *leopoldi* Bequaert, 1934, *nigrosericans* Bequaert, 1940, and *sibuyanensis* Bequaert, 1940. We concur that the subspecies category has no place in a phylogenetic system (Nixon and Wheeler 1990). Our observations showed that Yamane's grounds for separation of *sulcatus* are not upheld, and the "subspecies" of *P. tenebricosus* can be defined only by color patterns that intergrade, these having led us to synonymize all taxa treated as color varieties of *P. tenebricosus* by Bequaert (1934, 1940) under nominate *P. tenebricosus*.

Wasps collected on Sumba Island are so similar in structure to those from Flores



Figs 33–36. Nests. 33, 34, *Polistes diabolicus*. 35, *P. tenebricosus* from Sumba Island. 36, *P. callimorpha*. Scale bars: 20 mm (33, 34), 10 mm (35, 36).

that we should treat them as *P. tenebricosus*; **NEW RECORD** of this *Polistes* wasp from Sumba Island. On the other hand, they have a color pattern remarkably different from those from Flores and any other known color forms of *P. tenebricosus* as described below.

Color pattern of specimens from Sumba.— Brown to dark orange-brown, with following parts black: ill-defined spot around ocelli, lateral projections of clypeus (border ill-defined), mandibular teeth; flagellum except basal half of first flagellomere; anteroventral area of mesepisternum, spot on border between dorsal and ventral metapleura, most of ventral surface of mesosoma, ill-defined posteromedian spot on propodeum (markings on mesosoma sometimes reduced in size), basal parts of first and second metasomal terga, first sternum, basal part of second sternum, basal part of hind coxa, basal band of hind femur (often absent). First and second metasomal terga colored with bright yellow as follows (Figs 41, 42): most of posteroventral area of first tergum (anterior mar-

gin irregular and with fine, transverse, median, brown line);

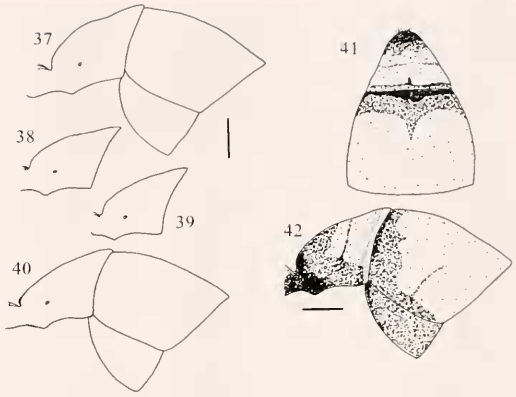
Mature larva.—Four mature larvae from two nests from Sumba were examined. Their coloration and structure were generally as those of *P. tenebricosus* from Luzon, the Philippines (Kojima 1984) and from Sumatra, Indonesia (Kojima and Yamane 1984).

Cranial width 3.1–3.4 mm (n = 4). Cranium and mouthparts blackish brown, but ventral margin of labrum often slightly paler; ecdysial sulcus, parietal band and center of antenna unpigmented. T1 venter largely dark grayish brown.

Structure (Figs 43–52) similar to that of *P. diabolicus*, but distinctly different in the following points: papillae on ventral margin of labrum and palate much reduced in size; galea (Fig. 48) with its apex slightly divided into four lobes, each of which has a small, apical sensillum (in one specimen, left galea with one lobe separated from the others by deep incision; Fig. 49); posterior margin of T1 venter with sparse spicules; T2-3 venter covered with dense spicules (Fig. 51); some spicules on T4-6 venter (Fig. 52) shaped ridge-like.

Nest.—Three nests were collected in Sumba Island; all were before the production of adults from the nests. Nest PS-1 was made on the upper surface of a limestone cave (about 1.5 m diameter) and had only eggs as immatures (Table 1). PS-2 and -3 were made close to each other (about 0.2 m apart from each other) under a roof of an outside kitchen; in both nests "tandem brood" was recognized.

Nest structure (Fig. 35) basically as that of *P. diabolicus* in early stage; comb bell-shaped, whitish-gray to gray in color, but brown to dark brown around pedicel attachment due to coating of salivary secretion; pedicel 5.1–7.7 mm (n = 2) long, 0.9–1.0 mm (n = 3) thick near mid-length; cell width 7.2–7.5 mm (n = 3); cell wall 0.04–0.10 mm (n = 3) thick; cocoon caps nearly white, barely domed, not produced beyond rim of cell.



Figs 37–42. Metasoma of *Polistes tenebricosus*. 37–40, wasps from Flores Island. 41–42, color pattern of a wasp from Sumba Island. 37, 40, 42, first and second metasomal segments, lateral view. 38, 39, first tergum, lateral view. 41, first two segments, dorsal view. Scale bars: 2 mm.

Adult wasps examined.—Flores: 2♀, 08°48'S 121°34'E, Baramari, Ende Selatan, 26.i.2003, JK; 2♀, 08°44'S 121°41'E, Detusoko, Ende, 26.i.2003, JK; 1♀, 08°47'S 121°25'E, Nangapenda, Ende, 25.i.2003, JK; 1♀, 08°45'S 121°34'E, Wolowaru, Ende, 26.i.2003, JK; 1♀, 08°51'S 121°41'E, Hotel Safari, Ende, 24.i.2003, JK. Sumba: 6♀, 09°42'S 119°53'E, Lewa, Sumba Timur, 30.i.2003, JK & RU (3♀, Nest#PS-2; 1♀, Nest#PS-3); 1♀, 09°55'S 120°39'E (120 m alt.), Umalulu, Sumba Timur, 29.i.2003, JK, Nest#PS-1; 1♀, 09°43'S 120°02'E (500 m alt.), Nggahariango, Sumba Timur, 30.i.2003, JK & RU.

Polistes (*Polistella*) *callimorpha* de Saussure, 1853

Since its original description based on females and male(s) from Timor (de Saussure 1853–1858: 71), this species has referred to only by du Buysson (1913: 228; from Kai Island) and in the checklist of *Polistes* species (Carpenter 1996a). This species is closely related to *P. stigma*, but can be distinguished from the latter by the head in dorsal view more strongly narrowed posteriorly behind eyes (Figs 53 *vs.* 54) and the propodeum not excavated (or

even slightly convex) in anterior half of its posterior face (very shallowly excavated medially in *P. stigma*). *Polistes stigma* occurs widely in the Oriental and Australian regions, represented by many local forms, but there are no records from Java and Lesser Sunda Islands (see Carpenter 1996a); we examined a female from Lombok Island (1♀, 08°32'S 116°15'E, Narmada, Lombok Barat, 7.xi.2000, J. Kojima), **NEW RECORD**, for comparison with *P. callimorpha*.

Mature larva.—Cranial width 2.2–2.4 mm (n = 8). Cranium (Fig. 55) grayish brown, with wide, transverse, whitish yellow band below level of antenna; mouthparts and body unpigmented.

Cranium in frontal view (Fig. 56) broadly rounded above, nearly parallel-sided ventral to level of antennae, about 1.3 times as wide as high; in profile (Fig. 57) shallowly emarginate posteriorly, with anterior margin bluntly angled near dorsal margin of clypeus. Integument of cranium, except for vertex and gena, covered with long (0.15–0.2 mm long) setae. Outer half of parietal band reticulate. Ecdysial sulcus narrow, very shallow. Antenna small, with three minute sensilla, two of which located very close to each other. Labrum (Fig. 58) narrowed where it joins clypeus, broadly and shallowly emarginate ventromedially, with about 50 setae; ventral margin with 5–6 elongate, conical papillae and sparse spicules. Palate (Fig. 59) with about 15 conical papillae medially; ventral and ventrolateral marginal areas with sparse spicules. Mandible (Fig. 60) with three teeth; median tooth short, less than one-third as long as outer and inner teeth, which sometimes have minute dents (Figs 61, 62). Maxilla (Fig. 63) with about ten rather long setae in apical half; upper surface with minute spicules, which are arranged in rows; maxillary palpus (Fig. 64) simple in shape, elongate cone-shaped, with 3–5 apical sensilla; galea (Figs 63–66) irregular apically, divided into three lobes to varying degrees, with apical sensillum on each lobe. Prementum circular (Fig. 63), with 6–9 setae in area dorsal to each labial palpus; area ventral to labial palpi with about 40 setae; labial palpus (Fig. 68) simple, shorter than maxillary palpus, flat apically, with four apical sensilla. Postmentum (Fig. 62) small, sparsely scattered with punctures.

Body integument covered with sparse, minute setae, except on A1–2 venter; setae on A1 venter long (0.2–0.25 mm long) (Fig. 69); setae on A2 venter short (about 0.03 mm; Fig. 70). Spicules on body integument ridge-shaped (Figs 69, 70), dense on anterior segments, becoming sparser on posterior segments; A9–10 without spicules. Dorsal lobes of abdomen lacking setae and spicules. First spiracle slightly larger than second one, which is about 1.4 times wider in diameter than succeeding ones.

Nest.—A nest (Fig. 36) made under main vein of a leaf of an unidentified broad-leaf tree at about 3 m from the ground was collected in a farmer's garden in Kupang, Timor Island. The nest had produced 12 adults judging from the presence of meconia.

Structural characters are as follows: comb (Fig. 36) rather irregular in shape, horizontal, and directed obliquely downward; upper surface (corresponding to cell base) slightly concave, except weakly convex area around pedicel attachment; comb color gray to brownish gray, with most of upper surface brown or dark brown around pedicel attachment due to coating of salivary secretion. Pedicel single, shiny blackish brown due to coating of salivary secretion, thickened exclusively by repeated coating of salivary secretion, 4.0 mm long, 0.8 mm thick near mid-length, attached subperipherally to comb. Cells slightly diverging toward open end, arranged generally regularly and hexagonal in shape at open end when they are surrounded by neighboring cells, but sometimes irregularly arranged, possibly due to diverging cell shape, in which they are

pentagonal or heptagonal at open end; cell width, mean ± SD = 4.3 ± 0.5 mm (range 4.0–4.7 mm, n = 9); cell wall about 0.05 mm thick, made of long fibers. Cocoon caps pale brown, slightly domed, projecting beyond rim of a cell by 3.5–4.5 mm (n = 10), without application of blotch of plant fibers.

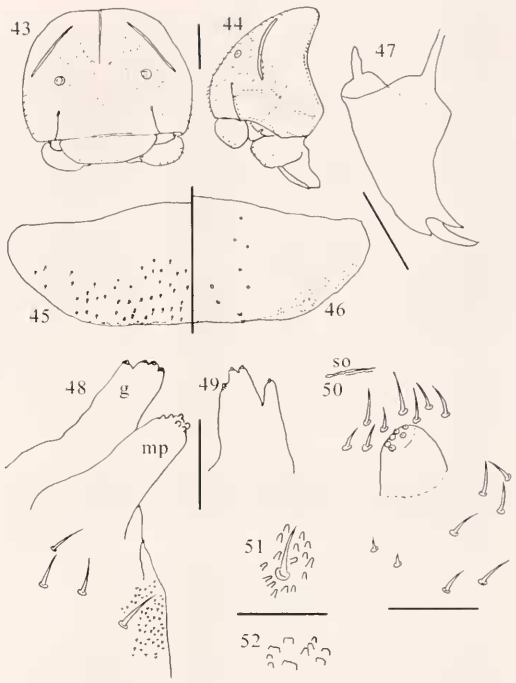
Adult wasps examined.—Sumba: 2♀, 09°43′S 120°02′E (500m alt.), Nggahaorian-go, Sumba Timur, 30.i.2003, JK; 2♀, 09°40′S 119°51′E, Sumba, Sumba Timur, 30.i.2003, JK (**NEW RECORD** for the island). West Timor: 3♀, 10°12′S 123°40′E, Fenonisa, Central Kupang, 23.i.2003, JK, Nest#PT-1; 1♀, 10°06′S 123°05′E, Kupang Timur, Kupang, 1.ii.2003, JK; 2♀, 10°13′S 123°50′E (360m alt.), Amarasi, Kupang, 2.ii.2003, JK; 2♀, 10°15′S 123°50′E, nr. Beherdi di Taman Raya, Kupang, 2.ii.2003, JK; 1♀, 09°57′S 124°09′E, Batuputih, Timur Tengah Selatan, 1.ii.2003, JK.

Polistes (*Polistella*) *sagittarius* de Saussure, 1853

Polistes sagittarius de Saussure, 1853, in de Saussure, 1853–58: 56.

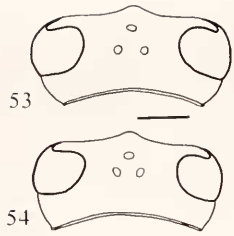
Polistes sagittarius var. (or subsp.) *indonesicus* Bequaert, 1940: 267. NEW SYNONYMY.

This species has been recorded from India, continental Southeast Asia and Palawan of the Philippines, and, in Indonesia, from Sumatra, Java, Bali and Sulawesi. Currently two color forms are recognized as subspecies: *P. s. sagittarius* and *P. s. indonesicus* Bequaert, 1940. Their differentiation is mainly based on color pattern of the first two metasomal terga, being mostly yellow or orange-yellow in *P. s. sagittarius* and entirely ferruginous in *P. s. indonesicus*. In the present field research, the species was collected only on Flores Island, **NEW RECORD,** and the specimens have a color pattern that generally matches that for *indonesicus*. Both forms (nominate *sagittarius* and *indonesicus*) have been recorded in Sumatra and Sulawesi (see Carpenter 1996a), and we have seen specimens from Sumbawa Island (2♀1♂, 08°30′S 118°33′E, Bolo, Bima, 11.xi.2000, J. Kojima; **NEW RECORD** for the island) representing intermediate color patters. The Museum Zoologicum Bogoriense houses a female from Sumba Island (Kananggar, 700 m, East Sumba, v.1925, Dammerman; **NEW RECORD** for the island), which also represents an intermediate color pattern. The taxon *indonesicus* is herewith synonymized under nominate *sagittarius* **NEW SYNONYMY.**



Figs 43–52. Mature larva of *Polistes tenebricosus* from Sumba Island. 43, head, frontal view. 44, head, lateral view. 45, Labrum. 46, palate. 47, mandible. 48, apical part of maxilla, showing maxillary palpus (mp) and galea (g). 49, galea. 50, labial palpus and structures around it including salivary opening (so). 51, 52, setae and spicules on T2 venter (51) and A4 venter (52). Scale bars: 1 mm (43, 44), 0.5 mm (45–47), 0.1 mm (48–52).

Adult wasps examined.—Flores: 2♀, 08°44′S 121°45′E, Detusoko, Ende, 26.i.2003; 5♀, 08°45′S 121°51′E, Wolowaru, Ende, 26.i.2003, JK; 1♀, 08°47′S 121°25′E, Nangapenda, Ende, 25.i.2003, JK; 1♂, 08°48′S 121°40′E, Ndona, Ende, 24.i.2003,



Figs 53–54. Female head, dorsal view. 53, *Polistes callimorpha*. 54, *P. stigma* from Lombok Island. Scale bar: 1 mm.

JK; 1♀, 08°40'S 121°20'E, Aesesa, Ngada, 25.i.2003, JK.

REMARKS ON THE *POLISTES* FAUNA IN EASTERN LESSER SUNDA ISLANDS

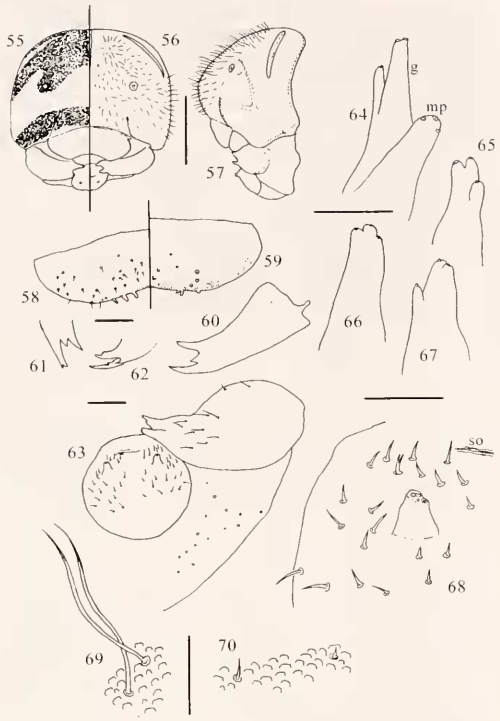
Two of the four *Polistes* species in the eastern part of Lesser Sunda Islands are undoubtedly of continental origin; for *P. tenebricosus* and *P. sagittarius*, Flores could be the extent of their eastward expansion. *Polistes sagittarius* is expected to occur on Lombok Island from which no records of this species are available. The Sumba population of *P. tenebricosus* represents a color pattern unique to this island. Sumba Island is known to harbor species or local forms endemic to the island, as illustrated with some other social wasps (*Ropalidia*: van der Vecht 1962, Kojima and Carpenter 1997; *Vespa*: van der Vecht 1957, Carpenter and Kojima 1997).

The occurrence of *P. diabolicus* on Sumba Island and the fact that this species has not been recorded in the areas west of Java may suggest its Lesser Sunda origin. The present study also recorded *P. callimorpha* from Sumba Island, suggesting close zoogeographic relationships among Timor and Sumba and that this species may occur also on Flores Island. In this respect, the distribution pattern of *P. diabolicus* and *P. callimorpha* with occurrence in the eastern part of the Lesser Sunda Islands and Kai Islands but not in New Guinea or Aru Islands is rather puzzling. Kai Islands are much closer in their geographical location to Aru and New Guinea than to Timor. The social wasp fauna in Kai is so far known to comprise seven species, of which *Polistes tepidus* (Fabricius, 1775) and *P. elegans* (Smith, 1859) are undoubtedly New Guinean elements, and *P. stigma* and *Vespa affinis* (Linnaeus, 1764) are widely distributed in the Oriental and Papuan areas (see Carpenter 1996a, Carpenter and

Table 1. Biological data of *Polistes* nests examined in Timor Island (*P. diabolicus* and *P. calimorpha*) and Sumba Island (*P. tenebricosus*) in 2003.

Species and nest code	Date	Height from ground (m)	Number of*					
			cells	eggs	larvae	pupae	empty cells	females
P. diabolicus								
PT-2	23 Jan.	ca. 2.5	123	72 (30)	71 (4)	22	0	7<
PT-3	23 Jan.	ca. 3.5	65	50 (5)	28 (1)	7	0	7<
PT-4	1 Feb.	1.7	54	24	29	0	1	3<
PT-5	1 Feb.	2.4	54	26 (9)	26	10	1	4<
PT-6	1 Feb.	0.7	57	31 (13)	27	12	0	3
P. callimorpha								
PT-1	23 Jan.	ca. 3	102	68	25	9	2	6<
P. tenebricosus								
PS-1	29 Jan.	1.5	16	15	0	0	0	1
PS-2	30 Jan.	1.7	18	8 (2)	5	3	4	3
PS-3	30 Jan.	1.7	23	10 (2)	7	2	6	1

* Numerals in parentheses indicate the number of eggs of larvae present in pupal cells or cells containing mature larvae. When some females escaped at collection, the numbers of females collected are given with "<".



Figs 55–70. Mature larva of *Polistes callimorpha*. 55, 56, head, frontal view (55, marking pattern; 56, structure). 57, head, lateral view. 58, labrum. 59, palate. 60–62, mandible. 63, maxilla, prementum and part of postmentum. 64, maxillary palpus (mp) and galea (g). 66–67, shape variations of galea. 68, labial palpus and structures around it including salivary opening (so). 69, 70, setae and spicules on A1 venter (69) and A2 venter (70). Scale bars: 1 mm (55–57); 0.2 mm (58–63); 0.1 mm (64–70).

Kojima 1997). *Ropalidia unicolor* (Smith, 1859) is endemic to Kai Islands, but *R. socialis* (de Saussure, 1862), the species most closely related to *R. unicolor* (Saita & Kojima, 2005), occurs in Timor while any species closely related to *R. unicolor* have never been known from Aru or New Guinea. Thus the distributional pattern of *R. unicolor* and its closely related species is similar to that of *P. diabolicus* and *P. callimorpha*. Nevertheless, occurrence of the two *Polistes* species on Kai yet needs confirmation. Von Schulthess (1935: 298) listed Kai for the distribution of *P. diabolicus* without giving any data for specimens or references. Du Buysson (1913) briefly referred to color characteristics of specimens from Kai Islands under *P. callimorpha*, which generally match characteristics of Kai population of *P. stigma* described as a subspecies, *tualenensis*, by Petersen (1987). Our knowledge of the social wasp fauna on the islands between Timor Island and New Guinea is still very poor, such knowledge should be the key to understanding diversification and dispersal processes of social wasps in the transition area between Oriental and Papuan areas.

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